HIRDLS **TC-LOC-1213**

HIGH RESOLUTION DYNAMICS LIMB SOUNDER

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Subject/Title: **VENTING OF THE HIRDLS INSTRUMENT DURING ASCENT**

Description/Summary/Contents:

The HIRDLS Instrument Technical Speciation (ITS) GSFC 424-28-21-13 Sec. 3.12.3.1.1 and Interface Control Document For HIRDLS EOS Common Spacecraft Project (HSICD) D26477C Sec. 7.3.1 require that there will be "sufficient vent provision shall be made to accommodate depressurization during launch and ascent." The purpose of this paper is to present the results of the venting analysis performed on the HIRDLS instrument to meet these requirements.

Keywords: Venting, Depressurization Rate, Differential Pressure

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VENTING OF THE HIRDLS INSTRUMENT DURING ASCENT

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Log of Changes

Rev.	Date	Section	Change Description
			Initial release.

VENTING OF THE HIRDLS INSTRUMENT DURING ASCENT

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1. SUMMARY

A venting analysis of the HIRDLS instrument subject to ascent on a Delta II launch vehicle was performed. Based on a conservative estimate of the available vent area it was shown that the differential pressures developed between the compartments during ascent are very benign and that the instrument clearly satisfies the requirements defined in the HIRDLS ITS Sec. 3.12.3.1.1 and HSICD D26477C Sec. 7.3.1.

2. REFERENCES

1. A. L. Lee and Y. A. Lee, "Ascent Venting of SIRTF Bus Bays," S&M-016, 5 October 1998.
2. A. S. Benson, "Venting Analysis," LMSC SS-162106262, May 21, 1981.
3. Mironer, A. and Regan, F., "Venting of Space Shuttle Payloads," AIAA 83-2600, 1983.
4. "Delta II, Payload Planners Guide" The Boeing Company 5301 Bolsa Avenue, Huntington Beach, CA 92647-2099.

3. INTRODUCTION

The primary compartments in the HIRDLS instrument that are to be vented are the Optical Bench Assembly (OBA) and the Structural Thermal Sub-system (STH). Due to the design of the instrument the preferential mass flow direction is from the OBA to the STH and then to the nose fairing of the launch vehicle.

To protect the optics in the OBA from contamination by the environment, it is isolated from the interior of the STH by the TSS Kapton Hood and other Kapton film closeouts. The hood and closeouts were primarily designed to prevent particle and molecular contamination during ground and mission operations.

The OBA is vented through a baffled path at its interface with the Aperture Door. When this door is closed, as required during launch, the main ascent vent for the OBA is into the STH. In addition there are other smaller baffled vents between the two levels of the OBA (above and behind the Chopper). The STH is primarily vented through the Baseplate Aperture, on the -z direction of the instrument and into the Electronics Unit (EU) through the cable chase. There are two vents out of the EU; 1) the vent around the contamination closeout (-x side) and 2) the vent spaces all around the electronics boxes. The STH is also vented through small vents located on the radiator, on the (+y) side, and others on the –y side of the instrument.

Figure 1 shows the venting plan for the HIRDLS instrument with the legend shown in Table 1.

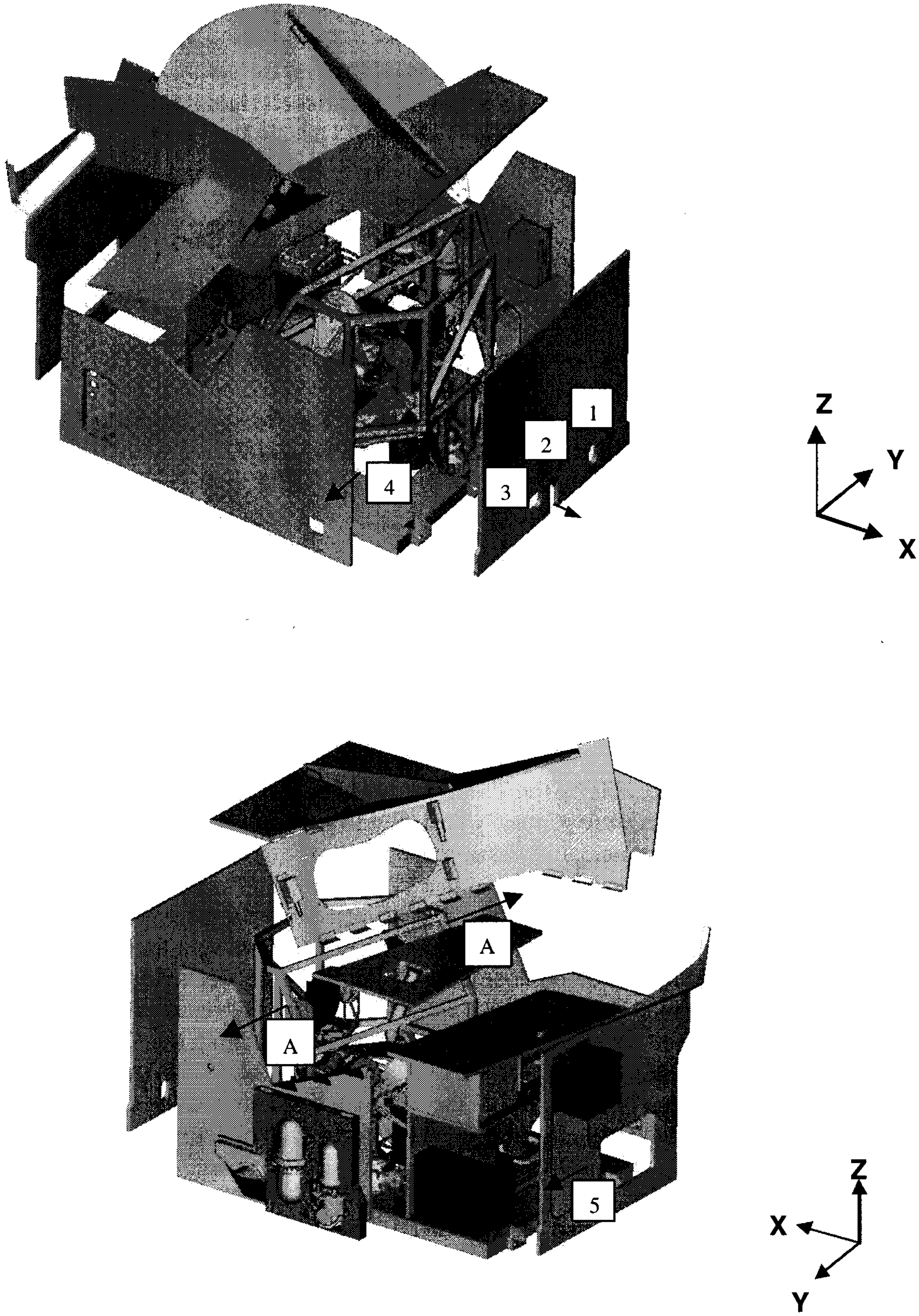

Figure 1: HIRDLS Instrument Venting Plan

Table 1: Legend for HIRDLS Instrument Venting Plan

Key	Vent Opening	Vent Length (in)	Comments
1	Vent STH to +y side	3.15	Small access hole vents under MLI
2	Vent to +x from STH	8.12	Small access hole vents under MLI
3	Vent of EEA and TEU to +Y side	2.76	not included in this analysis, taken care of in sub-system
4	Baseplate Aperture to -Z	41.72	GMU closeout
5	Electronics Compartment Aperture to -X side	9.45	This vent area does not include vents around e-boxes. Vents under MLI
A	SSH Aperture	25.48	Vents to STH when aperture door is closed.

4. VENTING MODEL

A venting model to predict the pressure in the enclosed cavities/chambers, during ascent or vacuum thermal testing, is shown in Ref.1. That model predicts the pressure in any system of *n* chambers based on the following formulation:

$$-V\frac{dP_i}{dt} = S_i \bullet P_i - Q_i + \sum Q_{ij}\left(P_i - P_j\right) \qquad i = 1,2\ldots n \qquad (1)$$

where *V* is the volume, *P* is the pressure, *S* is the pumping speed in the chamber, *Q* is the gas load and *t* is time. The subscript *i* denotes the properties of the *i-th* chamber. C_{ij} is the conductance between the *i-th* chamber and the *j-th* chamber. The system of first order simultaneous differential equations as given in Eq. (1) describes the vacuum system under simulation.

The HIRDLS instrument consists of two inter-connected chambers (OBA and STH) in series. HIRDLS has no pumps and that considerably simplifies the analysis to focus on just the conductance of the system. Conductance of a vent path is defined as the ratio of the flow and the pressure difference [2]. Its value depends on the flow conditions, which in the case of low altitude ascent venting can be modeled by continuum flow conditions.

Calculation of the conductance for venting flow in continuum flow is given by [2]:

$$\begin{aligned} w &= C_o g\rho A\frac{du}{dt} \\ &= \frac{C_o A P_i}{V}\sqrt{\frac{2\gamma}{(\gamma-1)RT_o}\left(\left(\frac{P_o}{P_i}\right)^{\frac{\gamma-1}{\gamma}}\right)\left(\left(\frac{P_o}{P_i}\right)^{\frac{\gamma-1}{\gamma}}-1\right)} \end{aligned} \qquad (2)$$

The pressure P_i refers to the pressure inside the vented chamber and P_o is the pressure outside the vented chamber. A is the vent path cross sectional area. C_o is the discharge coefficient. R is the gas constant and γ is the ratio of specific heats. However, this equation is only valid over the subsonic range, which is defined as

$$\left(\frac{2}{\gamma+1}\right)^{\frac{\gamma}{\gamma-1}} \leq \frac{P_o}{P_i} \leq 1.0 \tag{3}$$

The upper limit corresponds to zero flow while the lower limit of 0.528 corresponds for air (γ= 1.4) at the sonic condition.

Since we only have a two-chamber problem, rather than run a more complicated simulation we modified Eq. 2, so that the analysis could be performed on Excel®. The modified form of the Eq. 2 is shown below and is similar to that in Ref. 3:

$$\frac{d\ln\left(\frac{P_o}{\Delta P}\right)}{dt} = \frac{C_o A}{V}\sqrt{\frac{2\gamma}{(\gamma-1)RT_o}\left((\Delta P)^{\frac{\gamma-1}{\gamma}}\right)\left((\Delta P)^{\frac{\gamma-1}{\gamma}}-1\right)} \qquad \Delta P = \frac{P_o}{P_i} \tag{4}$$

The only unknowns in Eq. 4 are ΔP and C_o, as P_o is the pressure profile inside the nose fairing of the launch vehicle and can be obtained. The discharge coefficient, C_o, depends on the geometry and pressure ratio, in the subsonic range the typical value for an orifice ranges from 0.6 to 0.75 [2]. To be conservative a C_o of 0.6 was chosen for this analysis.

5. *PRESSURE OF DELTA LAUNCH VEHICLE ASCENT FLIGHT*

The pressure profile used in the venting analysis (dotted line) and the maximum and minimum pressure profiles, in the Delta II nose faring, from Ref. 4 are shown in Figure 2. The minimum pressure profile results in the maximum pressure differential across the instrument. The pressure profile used in this venting analysis is chosen to be close to the minimum pressure profiles but is not overly conservative.

The depressurization rate for this ascent pressure profile is shown in Figure 3.

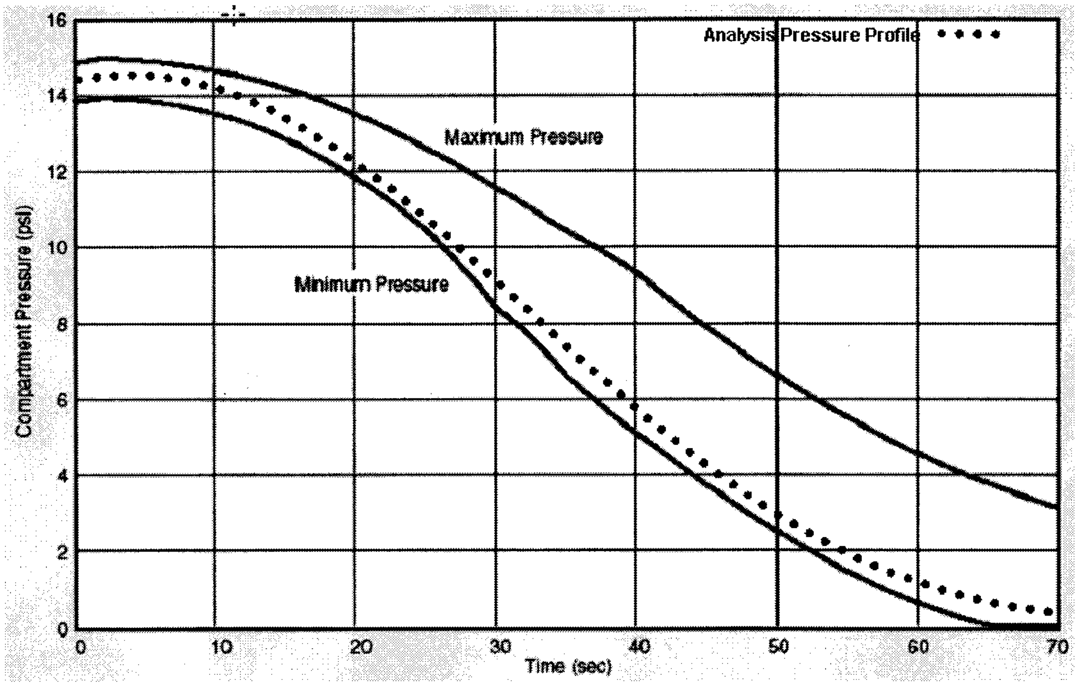

Figure 2: Delta II Payload Fairing Pressure In Ascent Flight

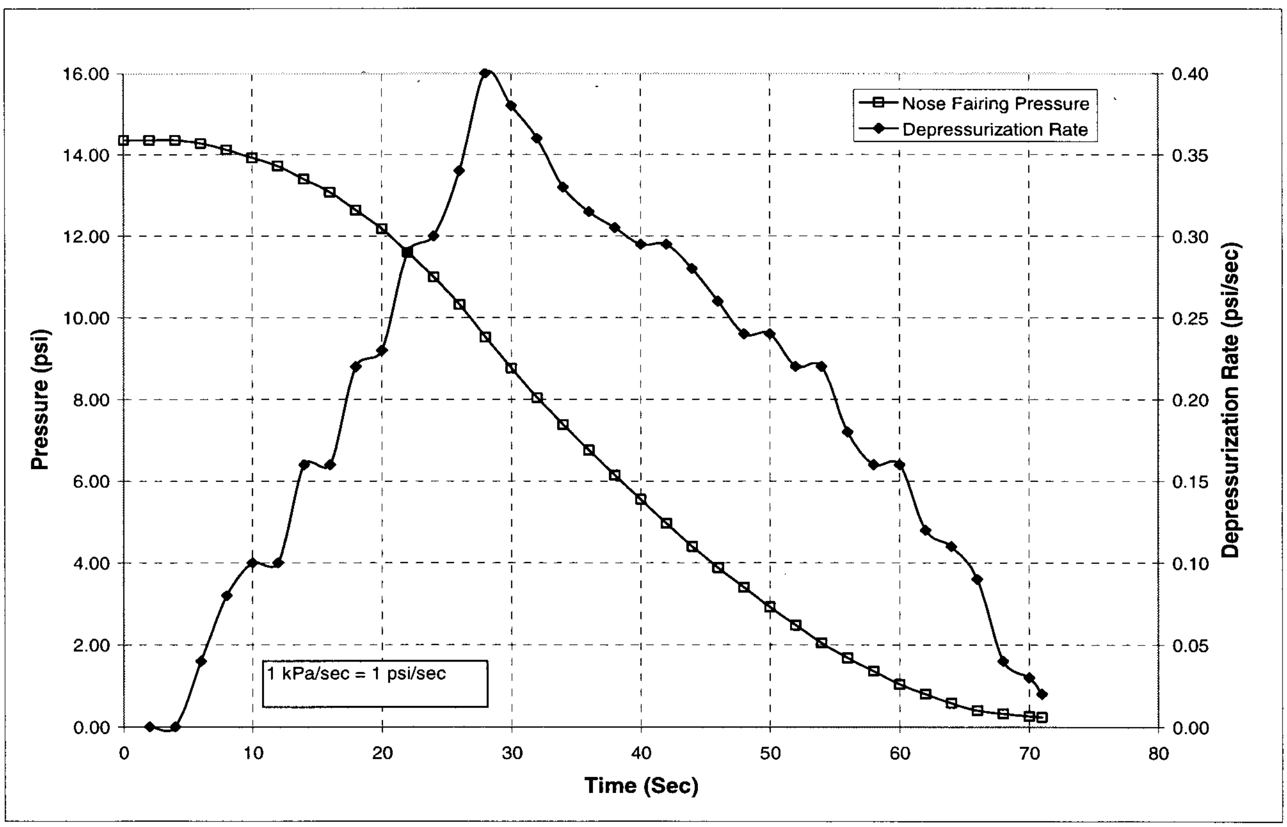

Figure 3: Depressurization Rate for Delta II Launch Vehicle

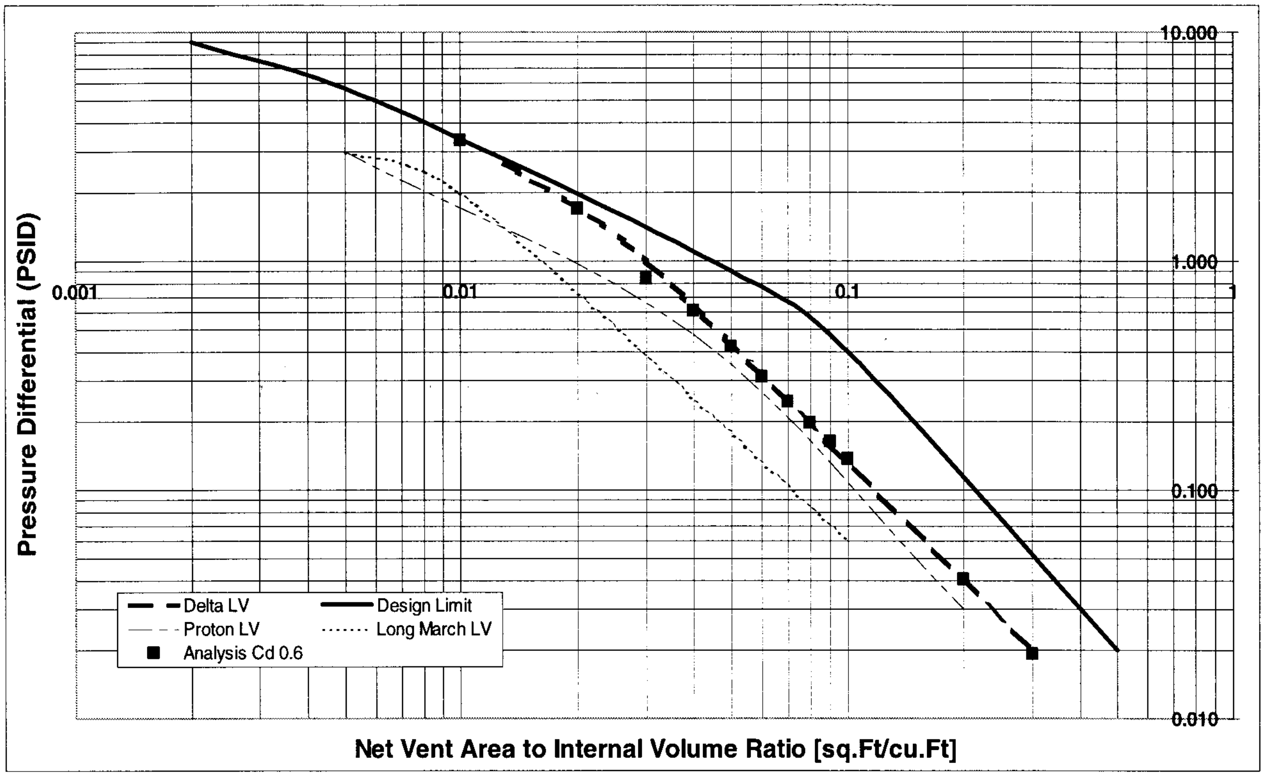

Figure 4: Ascent Pressure Differentials for HIRDLS and other Launch Vehicles (LV)

6. *PRESSURE IN THE INSTRUMENT DURING ASCENT*

The differential pressure during ascent is usually expressed as a function of net vent area to volume ratio in the unit of in^2/ft^3. The variation of differential pressure with net vent area to volume ratio for some common launch vehicles, namely Delta, Proton and Long March are presented in Figure 4 [1]. We validated our venting analysis by including our data, for this general case, in Figure 4. We obtained good correlation with the Delta LV curve when a C_o of 0.6 was used. The results obtained were below the line marked "design limit". Based on these results we chose to continue to use a conservative discharge coefficient of C_o =0.6 for this analysis.

The volumes of the chambers, to be vented, were obtained from the solid model of the instrument and are shown in Table 2. For the purposes of calculating the vent area ratio it was assumed that the STH and EU constitute one common chamber with the other being the OBA. Also, for this calculation it is assumed that only half the available length has been used to calculate the pressure drop during ascent.

The venting analysis of the instrument subject to ascent depressurization was performed using data from Table 2.

Table 2: Net Vent Area/Volume for Venting of Instrument

Chamber	Volume (m^3)	Available Vent Area* (in^2)	Net Vent Area/Volume (in^2/m^3)
OBA	10.989	3.185	0.299
STH	18.455		
EU	6.576		
STH+EU	25.031	8.150	0.325

* Assuming a vent opening (slit) width of 0.25 in.

7. CONCLUSIONS

Good venting design practice requires that the Net Vent Area/Volume ratio be at least 0.05 in^2/m^3 to limit the pressure differential between compartments to 0.5 psi [3]. As is evident from Table 2, the HIRDLS instrument venting area clearly meets the ratio requirement specified in Ref. 3. In addition, the pressure differentials at the compartment interfaces are quite benign as is shown in Figure 5, well below the 0.5 psi advocated in Ref. 3. This analysis shows that the venting capacity of this instrument is more than adequate for the launch and ascent in a Delta II launch vehicle and that the instrument clearly satisfies the requirements defined in the HIRDLS ITS Sec. 3.12.3.1.1 and HSICD D26477C Sec. 7.3.1.

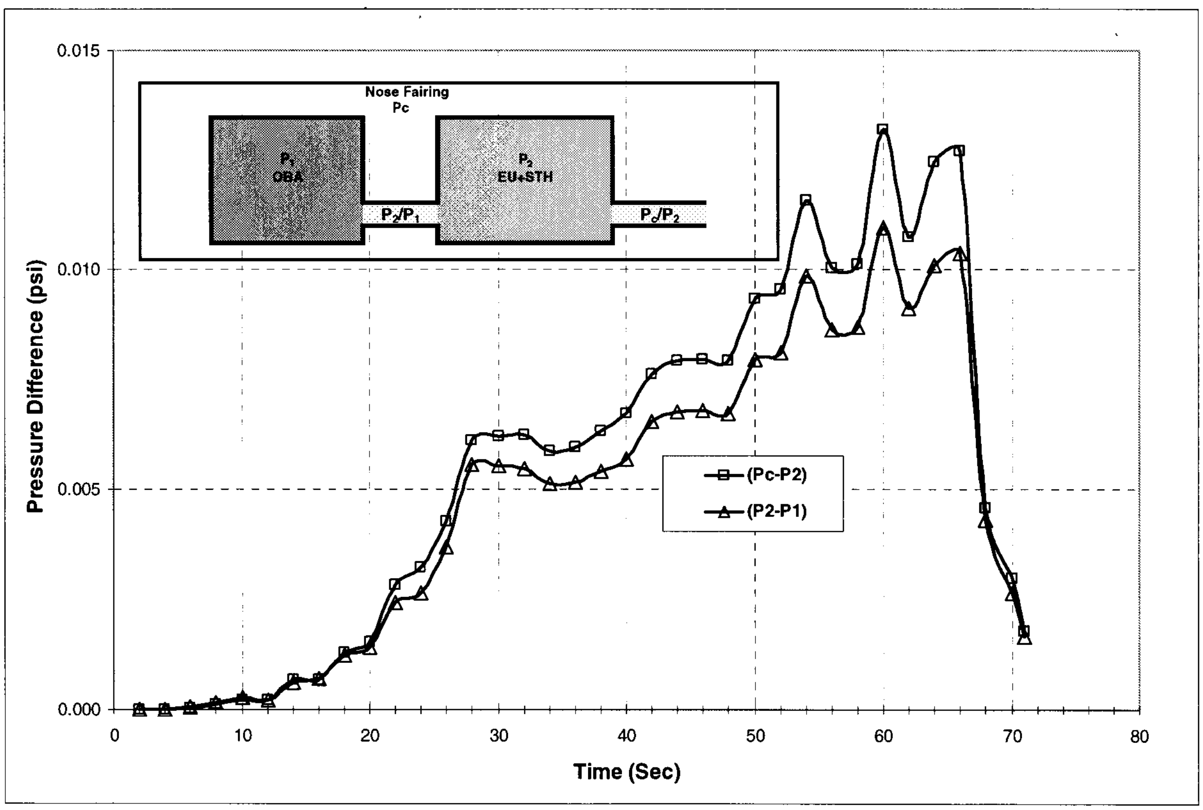

Figure 5: Pressure Differential between Venting Compartments (OBAS & STH)